

OPTICAL PHENOMENA IN PHOTOELASTIC COATINGS
IN THE INVESTIGATION OF SHELLS

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ABSTRACT

Deformation determination under rotation is discussed.

Coating thickness and rotation direction are considered.

Reference 1 shows that photoelastic coatings used in the investigation of shells may undergo a substantial rotation of the principal deformations which in turn may sometimes lead to substantial errors in determining these directions in the middle surface of the coating. The article by M. Kh. Akhmetzyanov (ref. 2) has shown that the errors caused by this in determining the components of deformation under certain definite assumptions are within the limits of accuracy of the experiment. Although we can agree with some of the conclusions reached by M. Kh. Akhmetzyanov, his general formulation of optical phenomena in the case of the rotation of the principal directions requires refinement. /86*

The basic conclusions of M. Kh. Akhmetzyanov are based on the proposition that the experimentally determined characteristic directions coincide with

*Numbers given in margin indicate pagination in original foreign text.

¹Tallin.

the directions of the principal deformations on the surface of the photoelastic coating. It follows from references 3 and 4 that this is approximately true for sufficiently large phase differences δ excepting the regions where $\delta \approx (2n + 1) j\pi$ ($n = 0, 1, 2, \dots$). In the latter regions which contract when n increases, the characteristic directions may differ substantially from the principal directions. Therefore the errors in determining the latter may also be greater than assumed in reference 2 when the values of δ are high.

Further it is stated in reference 2: "...with a decrease in the thickness of the coating the error introduced by the rotation of the principal deformations in the coating decreases and in the limit ceases to exist." This would be true if the proposition on the coincidence of the characteristic directions with the principal directions on the surface of the coating were always satisfied. As shown above, this is not so. Here the author has forgotten that the optical phenomena during the rotation of principal directions are of a nonlinear nature. Therefore although during the decrease in the thickness of the photoelastic coating, the error due to the rotation of the principal axis tends to decrease in general, the reverse situation may also occur. This follows from references 3 and 4 and can be simply illustrated by means of an example.

Let us assume that during the initial thickness of the photoelastic coating d the phase difference δ and the angle of rotation of the principal direction Φ_0 have the following values: $\delta = 510^\circ$, $\Phi_0 = 14^\circ$. From the nomogram presented in reference 4 it follows that in this case the error in determining the principal directions in the middle surface of the coating is equal to zero, since the angle α between the conjugate characteristic directions is equal to zero, i.e., the directional characteristics coincide with the principal directions in the middle surface of the coating. By decreasing the coating thickness

to $0.7 d$ ($\delta \approx 360^\circ$, $\Phi_0 \approx 10^\circ$), we have $\alpha = 10^\circ$, i.e., the error in determining the principal directions in the middle surface of the coating is -5° . Further we find that when the coating thickness is $0.39 d$ ($\delta \approx 200^\circ$, $\Phi_0 \approx 5.5^\circ$, $\alpha \approx 20^\circ$) the error in determining the principal directions is -10° while for a coating thickness of $0.31 d$ ($\delta \approx 160^\circ$, $\Phi_0 \approx 45^\circ$, $\alpha \approx -10^\circ$) it is approximately 5° . As the thickness is decreased further the error decreases to zero.

Thus during the decrease of the coating thickness there is no mono- /87
tonic decrease in the error incurred in determining the principal directions. It is precisely this point that was noted in reference 1 when it was stated that the decrease in the thickness of the coating does not make it possible to eliminate the effect produced by the rotation of the principal directions. As it follows from references 3 and 4 the monotonic decrease in the error during the decrease in the thickness of the coating takes place only when $\delta < \pi$. However, this region of phase differences is hardly of interest in practice.

Reference 2 does not present an entirely accurate explanation of the approximation used in reference 1. In the latter work it was assumed that the difference of the principal deformations is constant and that their directions rotate uniformly over the thickness of the photoelastic coating. The application of this approximation is due to the fact that this case has been studied in detail in the literature (refs. 3-5). Actually the difference of the principal deformations in the general case varies over the thickness of the coating and in the first approximation this variation may be considered to be linear. If the rotation of the principal directions were to be absent both of the approximations would be equivalent if in the first case we define the phase difference as the phase difference in the middle surface of the coating.

It can be assumed that this is approximately so also in the case of the rotation of the principal directions. Therefore, the phase difference determined by the method of reference 1 is known beforehand to pertain to the middle surface of the coating and not to the external surface as assumed in reference 2.

In conclusion we note that the deduction made by M. Kh. Akhmetzyanov that the error in determining the direction of the principal deformations produced by their rotation has a weak effect on the accuracy of determining the deformation components themselves, cannot be contradicted. However, if real optical phenomena are taken into account the errors in determining the principal directions may be substantially greater than those assumed in reference 2. In the theoretical analysis of the problem it is necessary to bear this in mind although it is quite possible that in practice such cases will be encountered seldom.

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